Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 99 (2015) 101 – 110

Procedia Engineering

www.elsevier.com/locate/procedia

"APISAT2014", 2014 Asia-Pacific International Symposium on Aerospace Technology, APISAT2014

Research on the New Airplane Develop System Based on 3D-Digital Technique and Multi-Companies Collaboration

Wang Qianping，Fan Lin*，Wu Xuhui

AVIC the first aircraft institute，Shaanxi Xi'an, 710089

Abstract

The paper mainly covers the Goal, the Plan and the Content of the New Airplane Develop System Based on 3D-Digital Technique and Multi-Companies Collaboration. Breaking through of several key techniques have been gained, including the product model definition technique based on the latest digital technique, whole airplane design/design modification automation response technique, multilevel concurrent engineering technique, modular design and technique state manage technique, multi-companies and multi-suppliers cooperating develop technique, large assembly butting technique , etc. Moreover, new airplane develop system based on 3D digital technique and multi-companies cooperating develop mode is formed, and it is successfully applied in the large aircraft development, and it has been proved that the design period of the product is shortened by more than 40%. The technique system can be applied to the aeronautics, the astronautics, the large ship, and the other manufacture domain according to its general characteristics. This technique has the comprehensive and profound function to promote our high technique development and improve the entire country's technique and capability.

Peer-review under responsibility of Chinese Society of Aeronautics and Astronautics (CSAA)

Keywords: Large aircraft; Digital technology; The collaborative platform; Modular

1. Introduction

As the most high-end aircraft product in aviation industry, large aircraft represents the overall scientific and technological level of a country. Innovative aircraft development system must be adopted to achieve success due to

* Corresponding author. Tel.: +86-29-86832975.
E-mail address: fanlin20000@163.com

Peer-review under responsibility of Chinese Society of Aeronautics and Astronautics (CSAA)
doi:10.1016/j.proeng.2014.12.513

the complexity in large aircraft development and the urgency in development mission. Large aircraft development shares the following features: 1) extra-large product size and part size and a huge number of part quantity, proposing a relatively high requirement for manufacturing system; 2) breaking through the traditional local realm development pattern of one institute and one factory; establishing the new pattern of cross-regional, multi-industry and multiple-factory joint development; means and standards must be adopted to break cultural differences and drive the units participating in the research to the similar technical level so as to solve the development short plank problem and cultural conflicts possibly caused by different levels of different units; 3) the product model defining method must be researched based on the latest digital techniques to ensure to maintain the sole data source during the entire development chain of hundreds of thousands of parts, reducing the design workload and meanwhile avoiding problems of non-uniform data expression and non-synchronous change of the traditional 3D+2D pattern; 4) manufacturing coordination and flow control technology for cross-regional and multi-industry complex design must be researched and developed, as well as the research and development of the full 3D top-level standard system covering design, manufacturing and management to ensure the orderly proceeding of multilevel parallel development efforts; 5) the complex project control technology must be researched and developed based on multiple suppliers so as to ensure the transparent and controllable project development progress and product technical status; 6) the engineering development environment that supports the entire development chain must be constructed to ensure that there is a collaborative working platform for all the engineers participating in the development. In the development of large aircraft, based on foreign development experience and lessons, we combine with the latest digital technical achievements to jointly research and develop super-large open-type cross-regional development system covering the design, manufacturing and management of large aircraft, and synchronously realize its application in the development of large aircraft projects.

2. Present Foreign and Domestic Research Status

The design and manufacturing means in foreign aviation enterprises has been fundamentally changed in recent years with the rapid development of digital technology. Since Airbus introduced 2D electronic pattern design at the early 1980s, it successively experienced the development history of 3D digital model, digital mock-up, digitalized factory and the digital technology based on the global network environment of knowledge engineering, which is shown in Fig. 1. Especially in the development of A380 Airliner which used product digital design, digital assembly technology, laser automatic tracking and laser radar scanning and measuring, automated control and other advanced digital technologies, reducing design change and rework rate and reducing assembly problems. However, the delivery of A380 was finally postponed for two years because Airbus was a loose federal group constituted by companies in many countries and lacked uniform planning, control and management in digital work; and different versions of the main software CATIA caused great troubles and difficulties in the data transmission and exchange between different units during collaborative design and manufacturing [1-2].

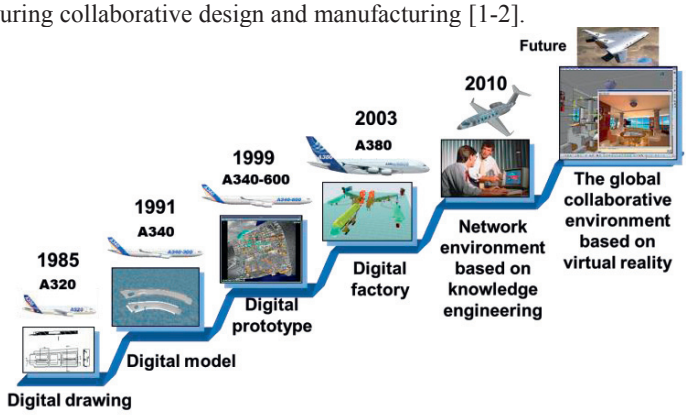

Fig 1. Airbus digital development technology development

On the contrary, in the middle of 1980s, Boeing Co. had made investment of CAD/CAM technology as the strategic direction for technological development. During the development of new aircraft model of Boeing 777, product 3D digital technology was comprehensively used, with total invested capital being over USD1 billion, making thousands of designers work at the same time in 2200 workstations connected with four IBM host groups, software such as CATIA, ELFINI (Finite Element Analysis System) and EPIC (Electronic Preassembly Integration on CATIA), etc. was used to proceed 100% 3D digital product design, digital preassembly and parallel product definition and storage of information of 3 million parts to the database, with the direct benefits of: canceling 3000 material sample pieces of assembly interface; reducing 90% engineering change and material reworking; enhancing 50 times of assembly precision, etc[1]. As a result, Boeing Co. further adopted more advanced digital R&D technology in the development of 787 Dreamliner Project, i.e., the GCE (Global Collaboration Environment) technical system based on model definition MBD opening the new era of digital aircraft engineering. As a new product information transmission model, MBD required the upstream designers to convert their own design ideas to the spatial 3D model, meanwhile integrating relevant information of manufacturing and inspection into the 3D model and making use of the original data sole for the aircraft product of the 3D model of the part for personnel for design, technology and inspection, etc. to directly develop aircraft product through this kind of 3D model.

In the early1990s, domestic aviation enterprises introduced CATIA 3D modeling technology and largely used By the introduction of CATIA 3D modeling technology in the early 1990s and starting with Flying Leopard, first realized full-aircraft 3D design, built the first digital model machine of full-aircraft in the country and realized the interference checking, disassembly analysis, movement mechanism analysis, achieving 100% digital part definition (DPD) based on the digital model machine and 100% digital preassembly (DPA), marking the prelude of aviation industry using digital means. In 2005, taking the opportunity of the development of ARJ21 new regional aircraft, the parallel design system across “two places” of Xi’an and Shanghai was built, realizing the cross-regional parallel design of physical scattering and logic unification; however, they only attempted partial parts and abandoned 2D drawings, directly sent the 3D model to the factory for production and carried out the tentative exploration of product full 3D collaborative manufacturing in different places due to lack of unity for digital R&D system of the design and manufacturing departments. From wide view of relevant researches at home and abroad, today with the highly developed information, it is of irreplaceable significance to implement advanced digital technology application research to meet the “blowout type” development of our aircraft at present and shorten the R&D cycle of aircraft.

3. A study on the Innovative Aircraft Development System Based on Full 3D Digital Technology and under the Pattern of Joint Development in Different Places

3.1. Technical Ideas

Construct the innovative aircraft development system based on full 3D digital technology and under the pattern of joint development in different places and form the new aircraft development standard specification and the digital platform that supports multiple institutes and factories parallel collaborative development of large aircraft on the basis of learning from relevant experience of foreign advanced aviation enterprises during aircraft development and in combination with the current development situation of domestic aircraft, which will then be used on large parts of the large aircraft; and after modification and improvement, use it for successful application on the full-aircraft to ensure the quality and node of large aircraft development, which are plotted in Fig. 2. Eventually, the brand new digital development system of our own will be formed, realizing the management innovation, technology innovation and product innovation in large aircraft development.

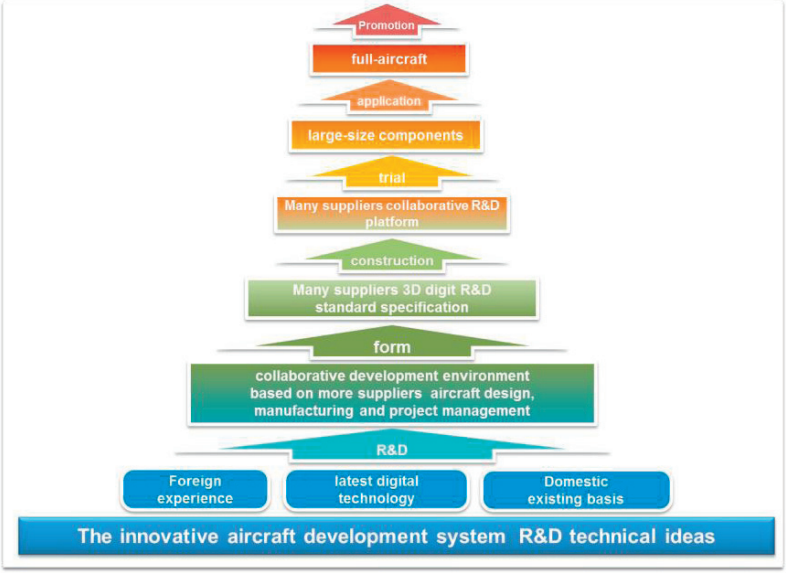

Fig 2. The innovative aircraft development system R&D technical ideas

3.2. Technical Plan

The research thought for construction of the innovative aircraft development system based on full 3D digital technology and under the pattern of joint development in different places is divided into (as shown in Fig. 3): partitioned construction and integral fusion. Partitioned construction means to break the technical bottleneck one by one to solidify the results to relevant standard specifications. Integral fusion refers to uniformly conclude and clear up the standard specifications formed by each partition to construct and form complete full 3D top-level standard system covering design, manufacturing and management and meanwhile to solve the issue of construction of engineering environment that supports the entire development chain. Partitioned construction mainly includes design method research of the product based on the latest digital technology, R&D of the automated parallel iterative response system for full-aircraft, R&D of engineering environment supporting the entire development chain and research on digital manufacturing technology, etc.; then through integral fusion, the purposes of unifying technology, management and platform in the entire development chain will be achieved and finally the innovative aircraft development system based on full 3d digital technology and under the pattern of joint development in different places will be formed that supports the entire development chain involved by all the suppliers [2-7].

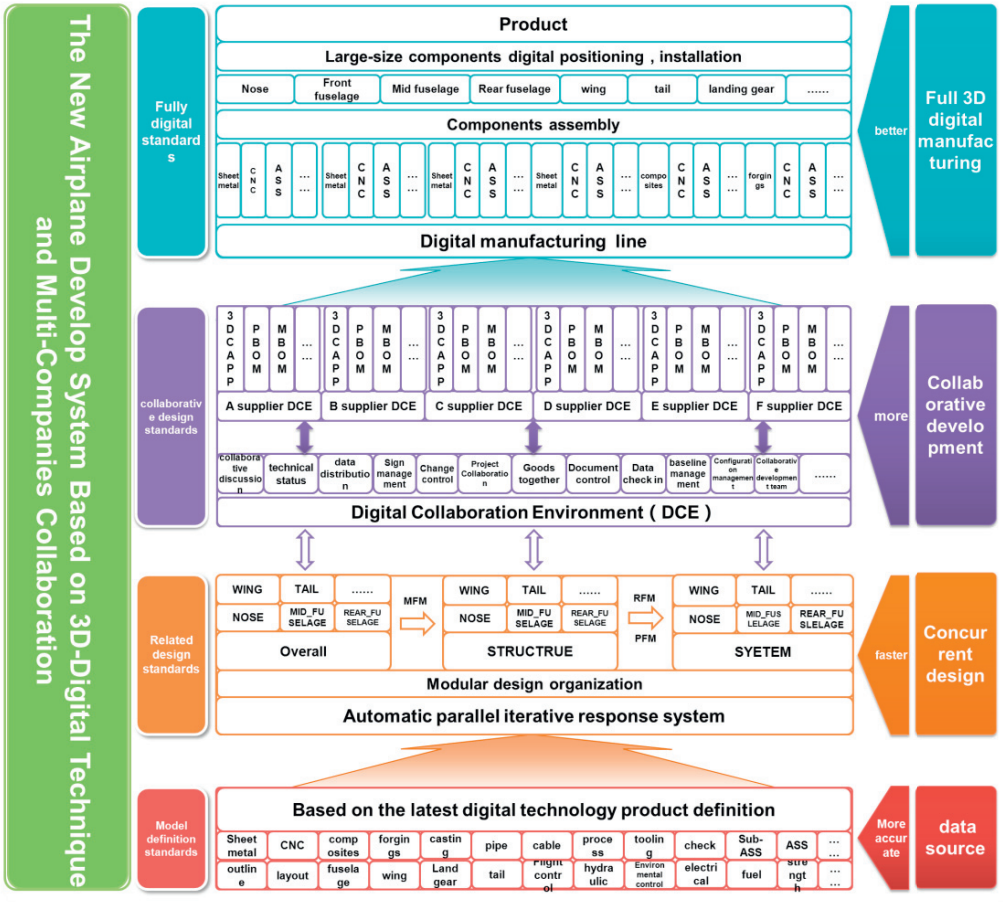

Fig. 3.The New Airplane Develop System Based on 3D-Digital Technique and Multi-Companies Collaboration Technical Plan

3.3. Main Technical Contents

The project technology realizes the parallel collaboration of multi-specialty and manufacturing of large aircraft design with the full 3D digital definition and associated design as the entry point, by virtue of advanced modular design and technical status management method and by making use of multidimensional maturity definition and control technology; realizes the efficient functioning of engineering R&D process through inter-enterprise and cross-regional digital process control technology; and realizes the high-quality manufacturing of large aircraft through full 3D digital manufacturing means, primarily changing the traditional aircraft development mode and R&D system. Meanwhile, a constitution is set up for the project development through the formulation of relevant standard specifications; platform for aircraft development through software and hardware development is built; the idea and rule through technical training is put into application; and brand-new collaborative design and manufacturing system of full 3D digital and in different places for large aircraft is finally formed that includes management process, development means, development support environment and standard specifications, which are plotted in Fig. 4.

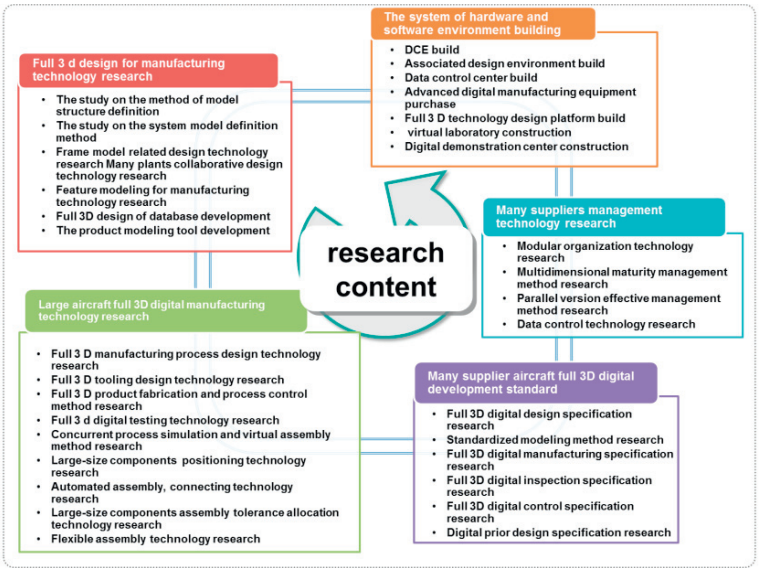

Fig.4.The New Airplane Develop System Based on 3D-Digital Technique and Multi-Companies Collaboration Main Technical Contents

- Manufacturing-oriented Full 3D Design Technology Research

The implementation of manufacturing-oriented full 3D design technology research breaks through the two key technologies of product full 3D definition and associated design. It first completes the definition method research of product based on the latest digital technology in the country, innovatively proposes overall master frame model (MFM), structural rational-deign frame model (RFM) and system frame model (PFM) concepts, successfully uses associated design technology in the entire design stage, researches and develops design/design modification automated response system and realizes multi-specialty and high-speed parallel design by analyzing the full 3D model of foreign advanced type and under the premise of comprehensively considering the manufacturing requirements of multiple suppliers, which are plotted in Fig. 5. Meanwhile, it independently develops a series of rapid modeling, optimization design and specification modeling tools in order to enhance the full 3D design efficiency and quality and maximize the benefits brought by full 3D to the design.

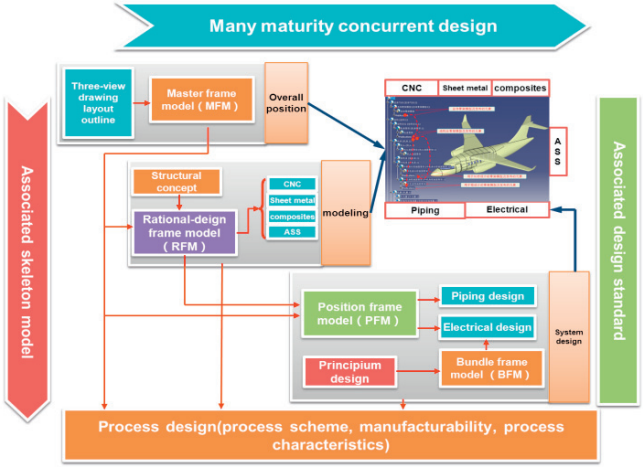

Fig. 5.Full 3D definition and associated design

- Full 3D Digital Manufacturing System Research for Large Aircraft

Through research on the extractive technique for full 3D design data information, design technique for full 3D manufacturability review process, manufacturing, inspection and process control method for full 3D products, specific design technique for full 3D manufacturing process, design technique research on full 3D model and EBOM digital assembly process, analysis on digital preassembly and assembly simulated verification process that is paralleled with the design, MBOM top-level structure technology of full 3D technique, the application technology of full 3D technique in technological equipment digital design, digital manufacturing process technique of full 3D technique, management technology of compilation and release of full 3D PBOM, management technology of full 3D process CAM data, design technique for full 3D inspection plan, full 3D digital detecting technology, research on establishment of full 3D process digifax, and full 3D process simulation and virtual assembly and other technologies, the full 3D digital manufacturing system research for large aircraft breaks through full 3D product process, technology equipment and inspection techniques, full 3D manufacturing of construction technology of PBOM and MBOM, and full 3D butt joint simulation technique for large parts with attentive efforts, forms the full 3D product information extraction and use method from data receiving, information extraction, AO/FO compilation, and product manufacturing to inspection, breaks through each link of product with full 3D data source, first organizes manufacturing departments to jointly compile the process file example collection based on full 3D and successfully constructs full 3D digital manufacturing system in multiple suppliers(See Fig. 6).

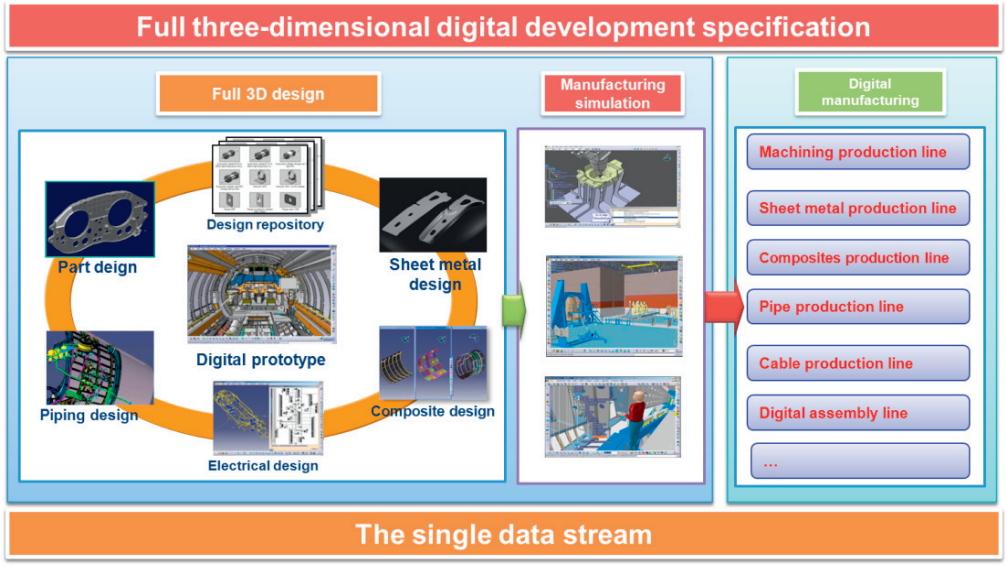

Fig. 6. Full 3D definition digital parallel collaborative manufacturing

- Multiple-factory Standard System Research Based on Full 3D

Through implementation of management method research on product maturity, management method research on product maturity, planning research on files of manufacturing management standard based on full 3D, in the multiple-factory standard system research based on full 3D, the management method of multidimensional product technology maturity covering the entire design flow is innovatively proposed (as shown in Fig. 7) to make the process interfere at the general planning stage and compilation of the basic outline of product digital definition design and manufacturing system based on model and other top-level standard files is completed, and the multiple-factory standard system based on full 3D on the basis of full 3D manufacturing flow and administrative provisions and other over hundred of internal files of multiple suppliers is established. Not only does the system standardize product full 3D definition method, design change and edition stipulation, data organization and status management, but also covers aircraft digital design, manufacturing, inspection and other technologies and management filed and

also multiple suppliers in aviation; featuring advanced technologies, complete content, wide covering range and strong practicability, etc. and passing the project use inspection, it can represent and lead the industrial development and can be promoted for other manufacturing industries.

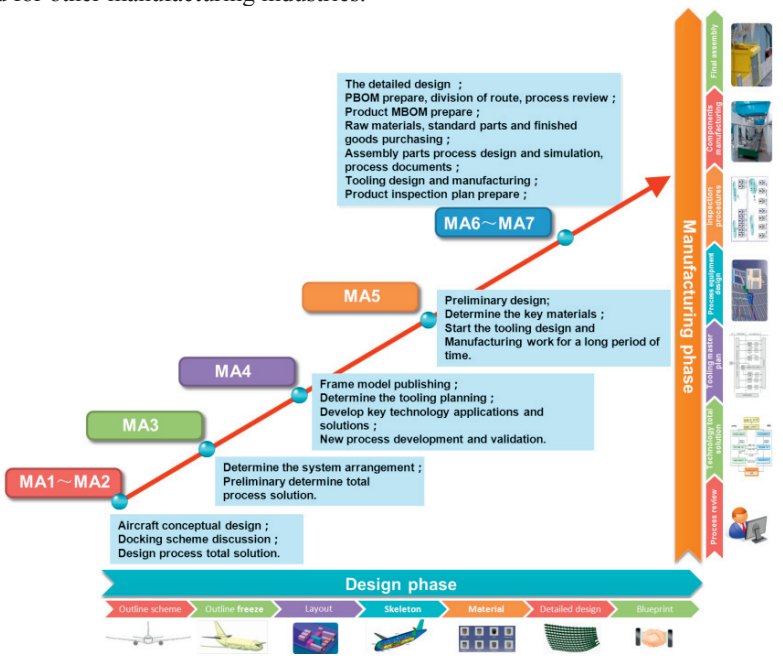

Fig. 7. Multidimensional maturity product management methods

- Technical Status Management System Research Based on Full 3D

Through manual or computer assisted management, previous project development realized the installed status accounting of key parts of aircraft, a method, liable to errors, and not combined closely with engineering change and with restricted management scope of technical status. Therefore, full 3D technical status management system research is carried out on the basis of absorbing the advanced management thinking of Boeing and Airbus and in combination with the reality of current domestic technical status management. Through the introduction of top chart concept, the thinking of combining aircraft module and data top chart is innovatively proposed: combine the configured and managed aircraft “large module” with top chart “small structure” controlled by single sortie effectiveness baseline to make top chart become the unit of product data organization, change and transmission to effectively flatten the full-craft data and simplify assembly level. Meanwhile, technical status management technology is conducted based on the technical status management of CI-CS-ECS and sortie management method research with parallelly effective multiple versions, and the combination of the configuration table and effectiveness baseline makes unified and standardized management of the effectiveness come true, reducing the complexity of effectiveness management, making the sortie effectiveness of the parts in the product structure completed automatically calculated by the system, simplifying the work of designer and ensuring the structure management and digital mock-up extraction under the parallel design environment as well as optimizing the scheme aiming the application practice of large aircraft. Thus, the technical status management system based on full 3D is finally established. In addition, strict control on the sortie structure is realized, the BOM of the full-craft is filtered according to sortie, and the correspondence and correlation of upstream and downstream data is realized, ensuring the uniqueness, effectiveness, traceability and completeness of the entire chain data of development.

- Construction of Software and Hardware Environment

Through strict software and hardware requirement analysis, detailed platform functional planning and reasonable filtering and matching of software and bidding and introduction of hardware equipment, software and hardware environment construction for multiple suppliers is implemented and digital manufacturing equipment system for large aircraft (Automated precise drilling equipment and multifunctional terminal are shown in Fig. 8) is constructed so as to meet the construction of multiple-factory full 3D digital collaborative design and manufacturing system and complete large aircraft development mission. Associated design environment, data control center and digital virtual demonstration and verification center, site visual platform are finally formulated and DCE platform and 3D process design platform, etc are constructed. Workers and inspection personnel can view relevant manufacturing basis and implement the manufacturing, assembly and inspection of parts through the visual system equipment on the industrial control computer set on the manufacturing site.

Fig. 8. Digital assembly field

4. Application effect

Previously foreign counties had adopted the mature full 3D digital design technology on new aircraft design, while the technology in the country only was still remained on the book research basis in colleges and universities and research institutes and was not truly applied in the specific development[8-9]. The R&D of the innovative aircraft development system based on full 3d digital technology and under the pattern of joint development in different places truly realizes the parallel design flow control of aircraft development and the form of imaging to demonstrate the recognition of the designer for the overall process of mission. The construction of agile response technical system for full-aircraft design/design modification driven on the basis of associated design includes skeleton pattern and its port definition, model reference and quote, automatic transmission of changed information and design auto update, geometric modeling of parts based on processing types and 3D dimensional tolerance annotation and manufacturing requirement expression and other methods; the realization of management and share of data based on sole data source includes defining method of structural design module, defining method of electrical system design module and defining method of piping system design module; the realization of parallel design of design and process and technology equipment, technical status management, user and authority management based on maturity control includes automatic calculation, interception and setting of effectiveness, state marking, checking, recording and control method of the engineering change flow; the realization of filtering method based on sortie effectiveness and establishment of digital positioning of large part butt joint and assembly production line provides solution to the rapid and correct assembly issue of extra-large parts of wing and fuselage, forming multiple digital production lines of machining, sheet metal, composite materials, pipeline pieces, electrical cables and assembly, etc., and breaking through digital design and manufacturing production line; digital inspection method based on model is formed and digital inspection of large aircraft manufacturing is realized; full 3D digital design and manufacturing standard specification system is formed that supports large aircraft development, full 3D digital design and manufacturing supporting platform (DCE) is established that supports large aircraft development, realizing parallel engineering of higher level to make each stage of design be able to analyze the conformity of the model to the requirement, achieving rapid development of scientized, automated and modularized complex aviation products.

5. Conclusion

The U.S. Boeing Co. and the European Airbus almost monopolize the entire international market and the large aircraft project is plagued with very complex and tedious operation mechanism issue, international airworthiness certification and market access issue, excessively high requirements for development and manufacturing capability as well as the international matching issue of engine and airborne equipment, etc. Therefore, the innovative aircraft development system based on full 3d digital technology and under the pattern of joint development in different places established through relevant technical researches breaks through the traditional design mode based on 2D pattern and brings about great changes to the development mode and flow: its development mode leads and drives the enhancement of the entire industrial development level and comprehensively improves the development quality and efficiency of aircraft. As preliminarily evaluated, the adoption of associated design technology can shorten at least 70% of the design iteration cycle, and the adoption of MBD design technology can shorten at least 40% of the design cycle, making the overall design cycle of the large craft be shortened at least 50%. Thus, the application of the technology makes information technology become the strong tool and core engine for the development of aircraft; the technology application not only drives each unit participating in the research to efficiently complete the development mission of large aircraft with high quality, but also drives the enhancement of social overall technology and capacity, featuring broad and deep social influence and significance.

References

[1] Fan Yuqing, Mei Zhongyi, TaoJie. Large Aircraft Digital Manufacturing engineering [M]. Beijing: Aviation Industry Press, 2011.
[2] Fan Yuqing. Modern aircraft manufacture technique [M]. Beijing: Beijing University of Aeronautics and Astronautics Press, 2001.
[3] Sudarsan R, Fenves S J, Sriram R D, et al. A product information modeling framework for product lifecycle management[J]. Computer-Aided Design, 2005, 37(13): 1399-1411.
[4] Sudarsan R, Subrahmanian E, Bouras A, et al. Information sharing and exchange in the context of product lifecycle management role for standards[J]. Computer-Aided Design, 2008, 40(7): 789-800.
[5] Janardanan V K, Adithan M, Radhakrishanan P. Collaborative product Structure management for assembly modeling[J]. Computers in Industry, 2008, 59(8): 820-832.
[6] Yang Lei. Management of Single Source of Product Data for the New Generation of Boeing 737 Tail Section[J]. Aeronautical Manufacturing Technology, 2003, (9): 59-63.
[7] Lu Hu, Yu Yong, Yang Wubing, et al Research on Integration Model of Single Source Aircraft Product Data [J]. Acta Aeronautica Et Astronautica Sinica, 2010, 31(4): 836-841.
[8] Wei Zhiqiang, Wang Xiankui, Wu Dan, et al. BOM multi-view mapping of product based on a single data source[J] . Journal of Tsinghua University (Science &Technology), 2002, 42(6): 802- 805.
[9] Yang Fang, Jiang Dan, Pan Lingyun. Application of 3D Assembly Order in Production Site[J]. Journal of Donghua University(Natural Science), 2012, 38(5): 560- 563.